Exogenous input estimation in Electronic Power Steering (EPS) systems

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Abstract

This document is a working report concerning the Task 5.1 of the project **VolHand 09 VTT 14** and refers to the paper [1]. This task is competence of the GipsaLab.
This report presents several aspects of modelling, observation and control towards a new generation of Electrical Power Steering(EPS) systems. In particular authors design an observer to estimate the driver applied torque (steering wheel torque) and the load torque (tire/ground contact friction). Simulation of the proposed control and observer are shown at the end of the document.

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1 Introduction

According to the document **ANR 09 VTT VOLHAND Doc B**, presented on **October 2011**, the research team in Gipsa-Lab is involved into the task 5.1 (T5.1) for the design of the control law to eliminate the high frequency oscillations of the steering column. To attempt to this job, the following steps have been done:

1. The study of a mechanical model of the Electronic Power Steering (EPS) system and design of an LQR regulator to reject the typical oscillations, due to the torsion of the steering wheel.
2. The design of an estimation of the full set of state variables as well as of the exogenous torques is carried out (Paragraph 2)
3. Modelling of the tyre/road contact friction, in order to test the mathematical model uder the most realistic conditions.
4. Study of the amplification curves, in order to provide the correct steering assistance to the driver.

The general architecture that authors propose to study the EPS system is shown in Figure 1. This report concerns the block 1 (observer/control) to estimate the driver's and load torque.

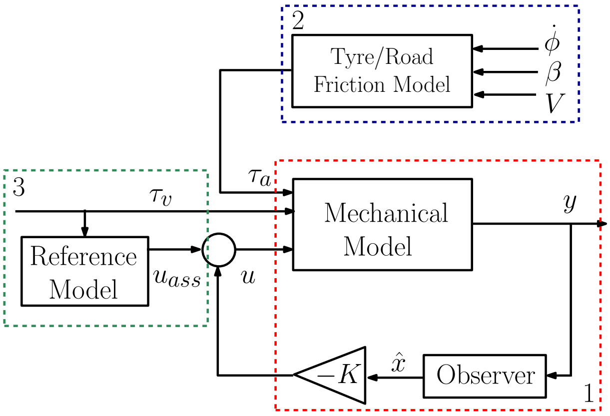

Figure 1: General architecture of the EPS system: block 1 concerns the observer and the control; block 2 includes the tyre-friction model and block 3 includes the reference model.

2 Extended state-space representation

Let consider that both exogenous torques are slowly time-varying: $\dot{\tau}_a = \dot{\tau}_v \approx 0$. The extended state-space representation of the EPS system, shown in [1], with z is now defined as follows:

$$\tilde{z} = \left(\dot{\theta}_v, \dot{\theta}_s, \theta_v - \theta_s, \tau_v, \tau_a\right)^T \tag{1}$$

in which both exogenous torques are added as state variables, is give by

$$\dot{\tilde{z}} = \tilde{A}_e \tilde{z} + \tilde{B}_e u \tag{2}$$

The state matrices for this system are shown below:

$$\tilde{A}_e = \begin{pmatrix} A & G \\ \mathbb{O}_{2\times 3} & \mathbb{O}_{2\times 2} \end{pmatrix}; \quad \tilde{B}_e = \begin{pmatrix} B \\ 0 \\ 0 \end{pmatrix}; \\ C_e = \begin{pmatrix} C & 0 & 0 \end{pmatrix} \tag{3}$$

If only the motor velocity $\dot{\theta}_s$ is used as a available output, then the observability matrix for this new extended system has rank 4 in spite of dealing with a system of dimension 5. To avoid this problem, it is possible to measure a second signal: the torsion force,

$$y_2 = k(\theta_v - \theta_s) = kx_3 \tag{4}$$

In this case, the output matrix C_e of the extended system becomes:

$$\tilde{C}_e = \begin{pmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & k & 0 & 0 \end{pmatrix}. \tag{5}$$

Computing the new resulting observability matrix, it can be easily check that it has now full rank. The system is then observable and it is concluded that both exogenous torques can be correctly estimated. The poles of the observer's dynamic (matrix $\tilde{A}_e - L_e\tilde{C}_e$) should be fast enough compared to those resulting from the linear controller.
The performances of the observer have been tested in simulations. The results obtained for the estimation of τ_v and τ_a are shown in Fig. 2(a) and Fig. 2(b). The maximum value reached by the observation error can be reduced at the price of increasing the observer gain. Measurement noise will limit at certain point the maximum possible value of the observer gain.

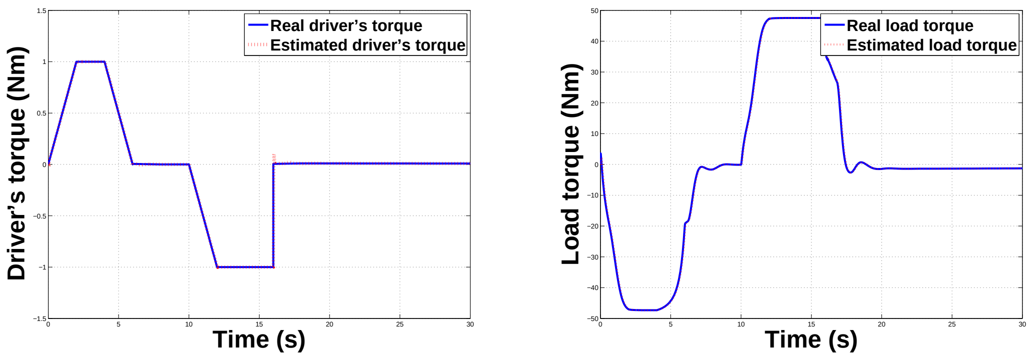

Figure 2: (a) Real driver's torque (solid) vs. estimated driver's torque (dotted). (b) Real load torque (solid) vs. estimated load torque (dotted).

3 Conclusions

This document presented simulation results of a satisfactory estimator of the exogenous torques acting on the EPS system.

References

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